INDOOR AIR QUALITY ASSESSMENT

Homer Street Elementary School
43 Homer Street
Springfield, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

In consultation with Judy Dean of the American Lung Association of Western Massachusetts, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA), provided assistance and consultation regarding indoor air quality at the Homer Street Elementary School, 43 Homer Street, Springfield, Massachusetts. Concerns about poor indoor air quality and sewerage system back-up and/or odors prompted this request.

On April 12, 2002, a visit was made to the school by Michael Feeney, Director of the Emergency Response/Indoor Air Quality (ER/IAQ) Program, BEHA, to conduct an indoor air quality assessment. Ms. Dean accompanied Mr. Feeney during the assessment.

The school is a two-story brick structure that consists of two wings. The original school building was constructed in 1898. A wing of ten classrooms was added to the original building in 1920. The 1920s wing had a cafeteria and four classrooms added to its east wall in 1925. Energy efficient windows were installed in two rooms of the building reportedly sometime after 1975. Windows are openable throughout the building.

An extensive evaluation of the school building was conducted by the engineering firm, Alderman and MacNeish Architects and Engineering (AMAE) in August, 2001. The following are recommendations made by AMAE concerning this building:

1. Replace the heating, ventilating and air-conditioning system;
2. Repoint red brick foundation wall;
3. Replace rotted floor joists in the basement classroom;
4. Remove all deteriorated brick mortar joints;

5. Replace missing and broken brickwork;
6. Install screens on rooftop gravity ventilators;
7. Install backflow preventer on the sewer line; and
8. Replace the plumbing system (AMAE, 2001).

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

The school has a student population of 260 and a staff of approximately 40. Tests were taken during normal operations at the school and results appear in Tables 1-4.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in twenty one out of thirty two areas surveyed, indicating inadequate ventilation in the building. A number of areas with carbon dioxide levels below 800 ppm were sparsely populated and would be expected to have increased concentrations with increased number of individuals in the room. Further, carbon dioxide levels in the building would be expected to increase over comfort levels during winter months when windows are closed due to the configuration and condition of the ventilation system.

Each wing has a fresh air supply system of similar design. A natural ventilation system exists with air intakes located in basement windows. The original system provided ventilation by a series of airshafts and louvered vents in classrooms that were connected to several air-mixing rooms located in the basement. Each air mixing room has a series of heating elements. With this type of system, air movement is provided by the stack effect. The heating elements warm the air, which rises up the ventilation shafts. As the heated air rises, negative pressure is created, which draws cold air from the basement window into the heating elements. A louvered or sash window located near the airshaft typically controlled fresh air in this type of system. Windows in the air mixing room are not used to introduce air during the operation of the ventilation system. Windows in the air mixing room are left closed. Air mixing rooms are currently being used for storage. The door to the air mixing room in the kitchen is left ajar (see Picture 1), presumably to have easy access to stored materials. This practice results in the distribution of basement air and cooking by-products into the upper floors of the wing, which is denoted in a previous BEHA letter (MDPH, 2002). Without introduction of fresh air, the buildup of normal environmental pollutants in the indoor environment can occur leading to air quality complaints. The recirculation of air in each wing results in reheating, resulting in increased temperatures and comfort issues.

A number of areas are not connected to the ventilation system. Some rooms were created by erecting walls in formerly open staircase balconies. These rooms do not have a mechanical means for providing fresh air and must rely on opening windows. The rooms are heated using wall-mounted radiators.

The 1898 and 1920/1925 wings have differently designed exhaust ventilation systems. The 1898 wing is drawn from the classroom into a grated hole located at floor level (see Picture 2). No airflow was detected in any exhaust vents examined. A flue located inside the duct controls airflow. Above the flue is usually a heating element that creates ventilation in the same method as the fresh air supply system. Exhaust vents terminate on the roof (see Picture 3).

The 1920/1925 wing had exhaust ventilation provided by large fans located in a brick cupola on the roof (see Pictures 4, 5 and 5A). Each fan is connected to classrooms by ductwork to a vent located on the interior wall of each classroom at floor level. The draw of air into these vents is controlled by a draw chain pulley system. The motor and fan belt for the exhaust system had been removed, rendering it inoperable. Without exhaust ventilation, environmental pollutants can build up in the indoor environment and lead to air quality complaints and discomfort.

During summer months, ventilation in the school is controlled by the use of openable windows in classrooms. Rooms were configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window, called a transom (see Picture 6) enables classroom occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open classroom transom, into the opposing classroom and finally exits the building on the leeward side (opposite the windward side) (see Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or transoms are closed (see Figure 2). Transoms in the 1898 and 1920/1925 wings are opened using a rod/hinge system. Most transoms in these wings are inoperable or closed. Some transoms are fixed in the closed position with nails.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult Appendix I.

Temperature readings ranged from 79° F to 82° F (with an outdoor temperature of 83° F), which were above the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 39 to 52 percent. Most areas sampled were within the BEHA recommended comfort range (see Tables). The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity in this building would be expected to drop below comfort levels during the heating season.

The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A number of opportunities for water penetration through the building envelope exist along the exterior wall/tarmac junction around the exterior of the building. The following is a list of conditions that allow for possible water penetration through the foundation walls.

- Plants were noted growing in the junction between the exterior wall and the tarmac (see Picture 7). Water can gather in the wall/tarmac seam where these plants were observed. Freezing and thawing of gathered water can result in damage to the exterior wall, which can result in water penetration into the building.
- Shrubbery in direct contact with the exterior wall brick was noted in several areas around the building (see Picture 8). Shrubbery can serve as a possible source of water impingement on the exterior curtain wall due to the location of plants growing directly against the building. Plants retain water and in some cases can work their way into mortar and brickwork causing cracks and fissures, which may subsequently lead to water penetration and possible mold growth.
- The exterior wall above the basement hallway has a number of holes and deteriorated mortar (see Picture 9).

- Downspouts empty at the exterior wall/ground junction onto leaves (see Picture 10) or several feet above ground level, which allows rainwater to impact on the ground below and chronically wet sections of the exterior walls. Downspouts should be designed to direct rainwater away from the base of the exterior walls to prevent rainwater from pooling against foundation walls. The wetting of exterior walls and crawlspace soil can result in mold growth.
- Piles of accumulated leaves in corners of the building can serve to hold moisture against exterior wall materials and increase moisture penetration.
- A large pile of sand exists outside the boiler room exterior wall (see Picture 11). Water runoff from the short roof onto the ground, combined with the sand pile, can hold moisture in this area, enhancing water penetration seen in the boiler room. The worst water damage in the boiler room exists directly opposite this sand pile.
- A peaked roof exists over a door at the rear of the school (see Picture 12). Water from half of this roof is directed toward a wooden window frame.
- A plant was growing inside the wire mesh on one ground floor window (see Picture 13). The presence of this plant indicates a sufficient water supply is wetting the material on top of this window frame to support plant growth.
- The roof over the classrooms of the 1925 addition does not have a gutter/downspout system. Rainwater rolls from the roof to chronically wet the foundation wall (see Picture 14).
- One downspout directs rainwater at the base of a fresh air intake for the 1898 wing. This may result in chronic moistening of the window frame and possible water penetration into the building.

Efflorescence (i.e. mineral deposits) was observed on the brickwork on the interior walls in a basement hallway with peeling paint (see Pictures 15 & 16) as well as the interior wall of the boiler room. Efflorescence is a characteristic sign of water intrusion. As moisture penetrates and works its way through mortar around brick it leaves behind these characteristic mineral deposits. This condition indicates that water from the exterior is penetrating into the building. Water damaged materials such as wall plaster can serve as a medium to support mold growth.

Several exterior doors appear to have water penetration through the door frame as noted by signs of water damage to the exterior of the door (see Picture 17). As with other porous building materials, if wood is not dried within 24 hours, mold growth may occur. Water-damaged wood may not be adequately cleaned to remove mold growth in some instances. The application of a mildewcide to moldy wood is not recommended.

Several classrooms had a number of plants. Plant soil and drip pans can serve as sources of mold growth. A number of these plants did not have drip pans or were in outdoor type planters with no drainage. The lack of drip pans and drainage can lead to water pooling and mold growth on windowsills when used indoors. Wooden sills can be potentially colonized by mold growth and serve as a source of mold odor.

Other Concerns

In an effort to reduce noise from sliding chairs, tennis balls are sliced open and placed on chair legs (see Picture 18). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas volatile organic compounds (VOCs). Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1998). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1997).

Open holes around utility pipes were noted in the floors and ceilings in classrooms (see Picture 19). Open pipes and utility holes can provide a means of egress for odors, fumes, dusts and vapors from the storage space into classrooms.

Both the teacher's room and 5A contained a photocopier without any means for local exhaust ventilation. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). Local exhaust ventilation may be needed in this area to help reduce excess heat and odors.

Several complaints of vehicle exhaust and fuel oil odors during fuel delivery were also reported. The pressure relief vent for the underground storage tank is located at the corner of the boiler room roof (see Picture 11). Under certain wind conditions, fuel oil vapor may be directed toward the classrooms adjacent to the boiler room roof. Cars are also parked at the base of the exterior wall near fresh air intakes for the unused ventilation system of the 1920/1925 wing (see Picture 20). Idling vehicles can result in vehicle exhaust infiltration into the building. In turn this can provide opportunities for exposure to products of combustion, including carbon monoxide. M.G.L. chapter 90 section 16A prohibits the unnecessary operation of the engine of a motor vehicle for a foreseeable time in excess of five minutes (MGL, 1986).

Some classrooms contained a number of empty soda cans. Improperly stored food and beverage containers can serve as a source of mold and mildew growth as well as a food source for pests.

Room 24 contains a laminator and dehumidifier. Dehumidifiers and lamination machines can give off waste heat. Laminators can produce odors. Mechanical ventilation should be activated while equipment is in use to help reduce odors in this room. Dehumidifiers should be cleaned/maintained as per the manufacture's instructions.

Of note is the use of cleaning materials in classrooms in the building. Cleaning materials frequently contain ammonium compounds or sodium hypochlorite (bleach-products), which are alkaline materials. The use of disinfectants in a building with minimized ventilation can expose an individual to ammonium compound vapors, which can lead to irritation of the eyes, nose or respiratory tract.

Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

A fireplace exists in classroom 8B (see Picture 21) which appeared to be no longer in use. The chimney for the fireplace is on the roof (see Picture 22). The top of the chimney is open, which can allow rainwater to penetrate down the shaft. In addition, animals may also enter the building through the chimney as well as via the 1898 exhaust vent termini.

Excessive chalk dust was observed in some classrooms. Chalk dust can be a respiratory irritant if aerosolized. Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were seen piled on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean in and around these areas. Dust can be irritating to the eyes, nose and respiratory tract. For this reason, items should be relocated and/or be cleaned periodically to avoid excessive dust build up. In addition, a number of exhaust vents in classrooms were noted with accumulated dust. If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles.

Sewerage Concerns

The building has a history of flooding from backup from the municipal sewer system (AMAE, 2001). The building was free of odors and sewage on the day of the assessment. Building staff report that sewage back up occurs occasionally in the restrooms located on the ground floor. In general, it is recommended that absorbent materials (e.g., gypsum wallboard, carpeting, fabrics, books, cardboard, etc.) be discarded once in contact with sewage (IICRC, 1999). Flooring and subflooring (such as wood and tile) should be evaluated, cleaned, disinfected, dried and sealed when appropriate (IICRC, 1999).

Conclusions/Recommendations

The conditions noted at the Homer Street Elementary School raise a number of issues. The combination of the design of the building and the condition of the ventilation system can adversely influence indoor air quality. For these reasons a two-phase approach is required, consisting of **(short-term)** measures to improve air quality and (**long-term)** measures (those listed in the AMAE report) that will require planning and resources to adequately address overall indoor air quality concerns. In view of the findings at the time of the visits, the following **short-term** recommendations are made:

1. Implement corrective actions recommended in the letter concerning the kitchen stove as soon as possible (see Appendix III).
2. Under current conditions, openable windows and doors are the only source of ventilation within this building. Long term solutions are advisable. Use of openable windows to provide fresh air in the interim should be done in a manner to prevent damage to the heating system from freezing pipes.
3. If the ductwork is determined to be useable with repairs, the following activities should be done:
   (a) Examine the feasibility of reestablishing ventilation control with existing ventilation equipment
   (b) Repair the pulley chain/louver door systems in vents to provide ventilation as designed.
   (c) Repair control systems for fresh air intake vents.
   (d) Repair the exhaust vent motors in the 1920/1925-wing cupola.

4. Use the sash windows in air mixing rooms to introduce fresh air into the building. Close doors in the air mixing room during the operation of the ventilation system.
5. Restore ability to open and close transoms. Use transoms to enhance airflow during warm weather. Be sure to close transoms at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a floor without interfering with the natural internal airflow pattern of the building. To aid cross ventilation, open hallway doors in areas with inoperable transoms.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
8. Repair/replace water damaged plaster. Examine surrounding non-porous areas for mold growth and disinfect with an appropriate antimicrobial if necessary.
9. Consider having exterior brick repointed to prevent further moisture penetration and subsequent water damage.

10. Remove the sand pile from close proximity to the boiler room.
11. Remove leaves from the base of the building.
12. Improve drainage along the exterior wall to direct rainwater away from the base of the building.
13. Cut back or consider removing shrubbery from the exterior wall of the front of the building.
14. Install a gutter/downspout on the peaked roof in Picture 12.
15. Remove all vegetation from the exterior wall/tarmac seam. Seal the exterior wall/tarmac junction with a water impermeable sealant.
16. Discontinue the use of tennis balls on chairs to prevent latex dust generation.
17. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
18. Clean chalkboards and chalk trays regularly to prevent the build-up of excessive chalk dust.
19. Consider installing local exhaust ventilation in the photocopier area.
20. Acquire current Material Safety Data Sheets for all products that contain hazardous materials and are used within the building, including office supplies, in conformance with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).
21. Schedule oil deliveries after school or when school is not occupied. If not feasible, notify school staff including classroom occupants in close proximity to the oil tank, in advance of scheduled delivery. This will avoid fuel odors/vehicle exhaust entrainment into classrooms.

22. Consider relocating parking spaces away from the building to prevent vehicle exhaust from being entrained by open windows.

23. Seal the abandoned chimney at roof level to prevent rainwater penetration and animal egress.

The following **long-term** measures should be considered.

1. Implement previous recommendations detailed in the AMAE report.

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Picture 1

Door To Air Mixing Room Ajar in Kitchen

Picture 2

Typical Exhaust Vent In 1898 Building Section

Picture 3

Exhaust Vent Terminus on Roof Of 1898 Wing

Picture 4

Cupola Housing 1920/1925 Wing Exhaust System

Picture 5

Abandoned Exhaust Fan System Of The 1920/1925 Wing

Picture 5A

Motors For the Abandoned Exhaust Fan System Of The 1920/1925 Wing

Picture 6

Typical Transom over Classroom Hallway Door

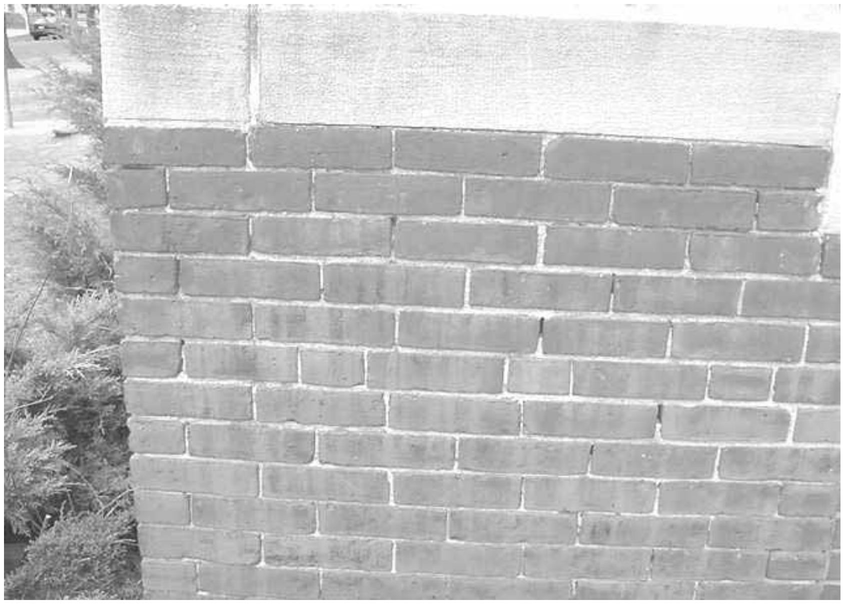
Picture 7

Plants Growing in the Junction between the Exterior Wall and The Tarmac

Picture 8

Shrubbery in Direct Contact with the Exterior Wall Brick

Picture 9



Deteriorated Mortar between Bricks of the Exterior Wall

Picture 10

Downspouts for This System Empty at the Exterior Wall/Ground Junction onto Leaves

Picture 11

Fuel Oil Tank Vent Pipe

Sand Pile

Pile Of Sand outside Boiler Room, Note Oil Tank Vent Pipe Location at Same Level as Windows

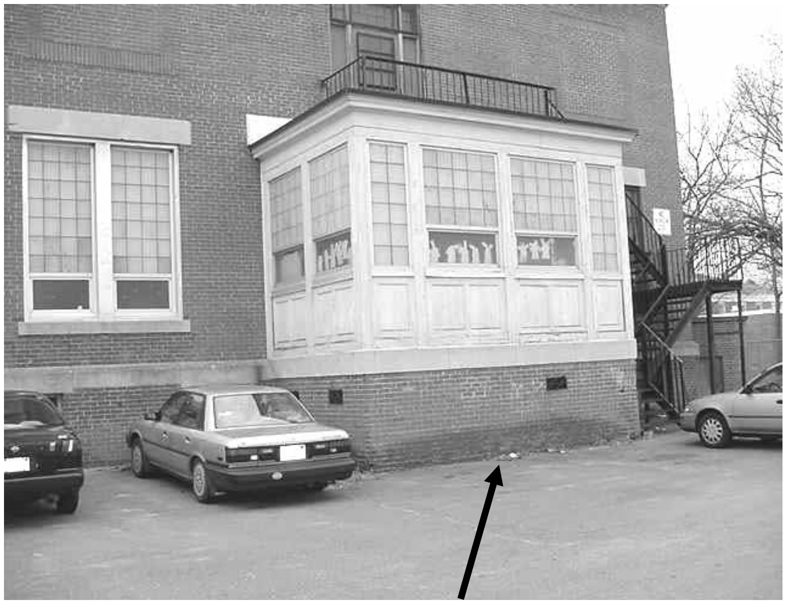
Picture 12

Peaked Roof over Doorway That Directs Rainwater toward Window

Picture 13

Plant Growing in Ground Floor Window Frame

Picture 14



The Roof over the Classrooms Of the 1925 Addition Does Not Have A Gutter/Downspout System, Note Water Stain at Base of Exterior Wall

Picture 15

Peeling Paint and Efflorescence in Ground Floor Hallway Of 1898 Wing

Picture 16

Efflorescence on Exterior Wall of Basement

Picture 17

Water Damaged Exterior Door

Picture 18

Tennis Balls On Chair Legs

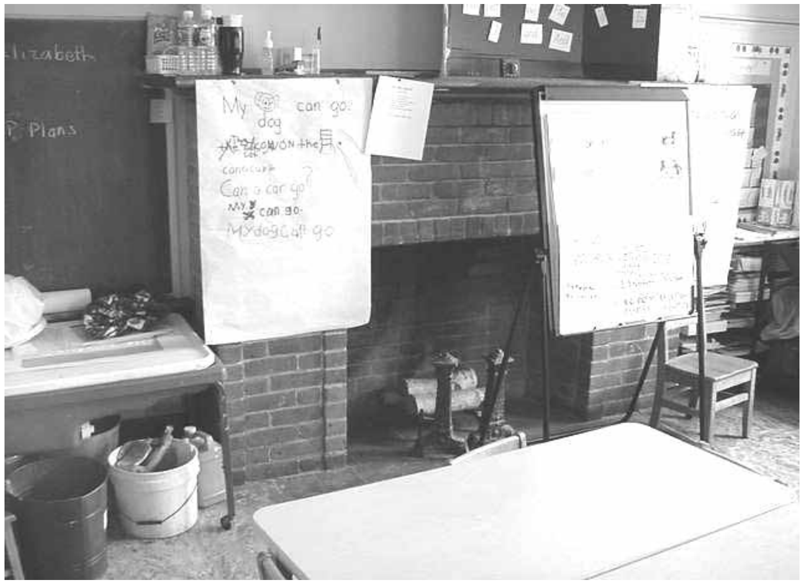
Picture 19

Holes Around Drain Pipes in Floor

Picture 20

Cars Parked At the Base of the Exterior Wall near Fresh Air Intakes for the Unused Ventilation System Of The 1920/1925 Wing

Picture 21



Fireplace in Classroom 8B

Picture 22

Chimney on Roof

TABLE 1

Indoor Air Test Results – Homer Elementary School, Springfield, MA – April 12, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	417	66	44					
New Wing – 2nd Floor								
Room 20	1063	69	38	22	yes	yes	yes	window and door open, supply and exhaust off, water damaged plaster, transom closed, dry erase board
Room 19	1189	71	39	15	yes	yes	yes	transom closed, supply and exhaust off, transom closed, door open
Room 20A	852	70	30	0	yes	no	no	transom closed, flour
Room 21	760	70	36	8	yes	yes	yes	window and door open, supply and exhaust off, exhaust blocked by crate, chalk dust, soda, transom closed
Room 21A	1467	71	37	0	yes	no	no	transom closed, door open
Room 18	764	71	36	17	yes	yes	yes	window and door open (wide), supply and exhaust off, transom closed, scented odor
Room 22	1257	71	38	20	yes	yes	yes	supply and exhaust off, transom closed, door open
Room 17A	1114	72	37	7	yes	yes	yes	supply and exhaust off, transom closed

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Homer Elementary School, Springfield, MA – April 12, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 17	671	73	33	15	yes	yes	yes	window open, supply off, exhaust blocked by desk
Staff Room					yes	no	no	window open, photocopier
Room 5A						no	no	photocopier
Janitor's Closet						no	no	mops
Room 6	828	72	36	13	yes	yes	yes	supply and exhaust off, door open, energy efficient windows, transom closed
Room 11	783	71	34	7	yes	yes	yes	supply and exhaust off, transom closed, door open, accumulated items, scent
Room 6A	640	73	36	4	yes	no	no	transom closed
Room 10	788	73	33	2	yes	yes	yes	supply and exhaust off, transom closed
Room 7	623	73	34	1	yes	yes	yes	supply and exhaust off-box blocking exhaust, transom closed
Room 9A	1269	72	35	0	yes	no	no	dry erase board, floor holes

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results – Homer Elementary School, Springfield, MA – April 12, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 9	697	71	34	0	yes	yes	yes	supply and exhaust off-exhaust blocked by cases, door open
Room 8B	1177	72	36	23	yes	yes	yes	transom closed, door open, supply and exhaust off, chimney
Room 8A	841	73	35	21		yes	yes	supply and exhaust off, soda cans, energy efficient windows, accumulated items
Cafeteria	1269	73	36	60+	yes	no	no	
Kitchen	1401	74	39	4	yes	no	yes	exhaust off, gas stove with pilot light
Room 9B	1239	73	34	13	yes	no	no	
Room 26	875	74	36	25	yes	no	yes	
Room 24	766	76	33	5	yes	no	no	lamination machine, dehumidifier. water, possible floor sag
Old Wing								
Room 16	896	72	35	24	yes	yes	yes	window and door open, supply and exhaust off
Room 15	838	72	33	8	yes	yes		window and door open, plants, supply off, tennis balls, accumulated items

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 4

Indoor Air Test Results – Homer Elementary School, Springfield, MA – April 12, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 14	860	73	33	21	yes	no	yes	window open, tennis balls, leaves in base of exhaust vent
Room 14A	846	73	33	8	yes	no	o	dry erase board, door open
Room 13A	874	72	33	8	yes	no	no	window and door open, plants, dry erase board
Room 5	800	72	34	0	yes	yes	yes	supply and exhaust off, door open
Room 1	799	71	33	0	yes	yes	yes	supply and exhaust off- exhaust louvers closed, door open
Room 4	790	72	34	2	yes	yes	yes	supply and exhaust off, water-damaged ceiling plaster, interior window
Room 2	1008	71	35	10	yes	yes	yes	supply and exhaust off, water-damaged plaster, spray cleaner
1st Floor Hallway								water-damaged plaster

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

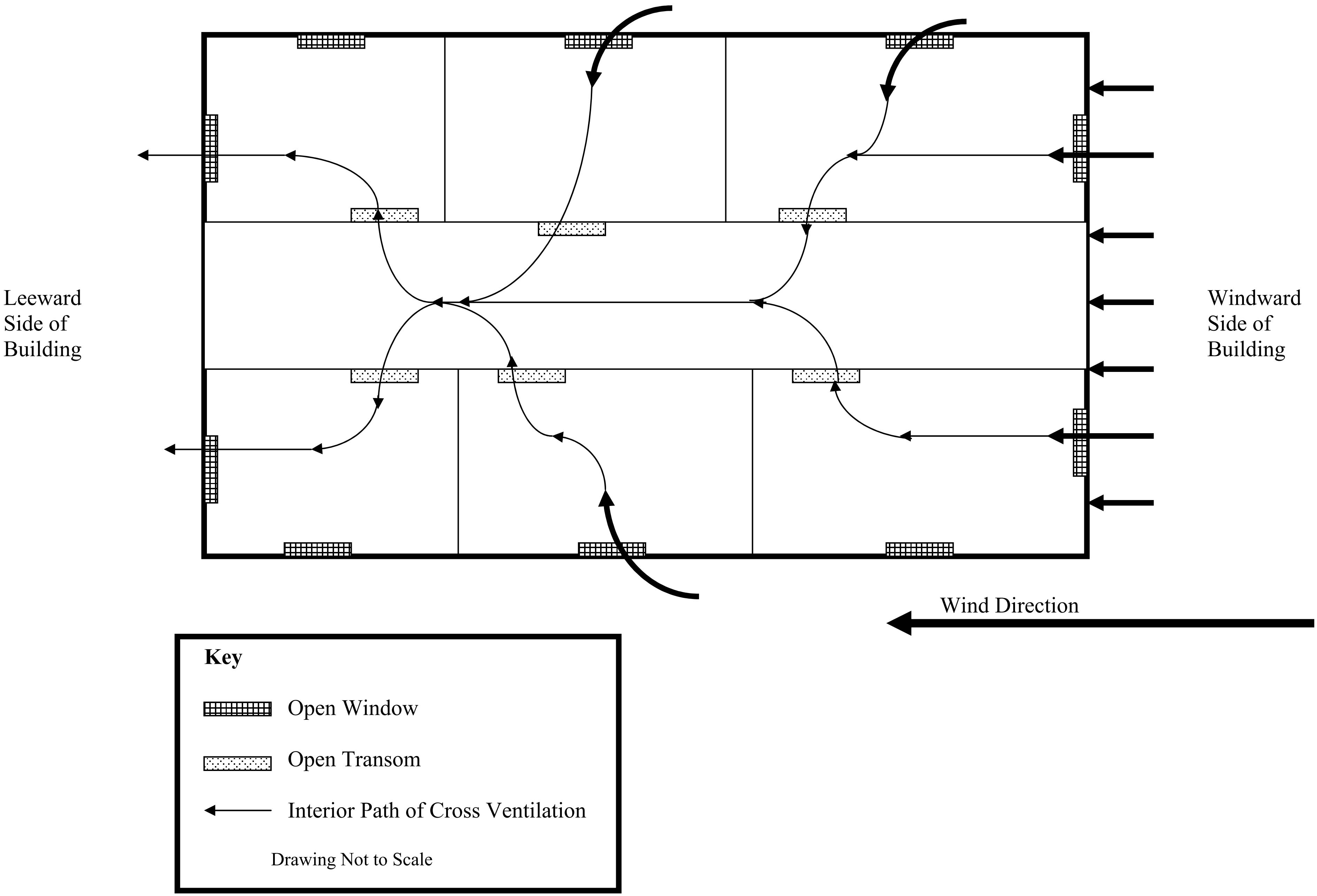


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**